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A large number of experiments were made with lenses, etc., submerged in mercury iodide solution, data for which there is no room here. The curious result appeared that if the solution refracts more strongly than the submerged glass, and the lens is well centered as to the beam of light, the ellipses remain strong and clear. Hence the refraction of the solution and of the glass need not be identical. The dispersion B is particularly well determinable. The refraction at λ in this case will be subject to

$$K' = \mu' - 1 + 2B'/\lambda^2 = \mu - 1 + 2B/\lambda^2 + \Delta N/e$$

when ΔN is the displacement produced on submerging the lens of thickness e at its middle and primes refer to the solution. The following is an example of results. K' for the solution is found as a whole from the full and empty trough.

Lens	e *cm.*	K'	ΔN *cm.*	μ	
1 diopter	0.138	0.6140	0.0078	1.5315	Ellipses strong
2 diopters	0.200	0.6140	0.0107	1.5345	Ellipses strong
5 diopters	0.248	0.6140	0.0187	1.5126	Ellipses faint
10 diopters	0.447	0.6343	0.0205	1.5625	Ellipses vague

The first two cases are good, the last two untrustworthy. To perfect this method a solution must be found whose dispersion constants are not so enormous compared with glass as the mercury iodide solution.

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[1] Note from a Report to the Carnegie Inst. of Washington.

[2] *Washington, Carnegie Inst., Pub.*, No. 249, 1916, chap. ix, cf. *Amer. J. Sci., New Haven*, **40,** 1915, (299–308).

[3] Mr. R. W. Cheshire, *Phil. Mag., London*, **32,** 1916, (409–420), has recently used Töpler's method for the same purpose with marked success.

[4] *Washington, Carnegie Inst., Pub.*, No. 229, 1915, § 40, 41, 42.

THE FOOD OF DROSOPHILA MELANOGASTER MEIGEN

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In May, 1916, while rearing the banana fly on artificial media of fermented banana agar,[1] I observed that visible fungus growths seldom occurred in the presence of many larvae. Such growths did appear, however, after pupation or if only a few larvae were present. Examination showed the surface growths to be largely yeast cells.

Further investigation showed that adult flies, pupae, larvae, and eggs invariably carried yeast cells and often had a rod-like bacterium upon them. This made it appear that an internal symbiotic relationship existed comparable to the notable cases of the flesh fly,[2] in which a micrococcus is passed through the egg and aids the larvae in the digestion of albumins, etc., the cockroach,[3] which has certain cells of the fat-body reserved for yeast, and many plant bugs,[4] which have caeca of the alimentary tract containing certain bacteria.

In the following experiments undertaken to show that microorganisms are not transmitted through the egg of Drosophila, the first precaution was to free the insect from external microorganisms. Usually eggs were used for this purpose but their small size makes this a difficult procedure. As it is well known that the lining of the digestive tract of larvae is thrown off upon pupation, pupae were selected for sterilization.

(1) The pupae were submerged in 85% alcohol for ten minutes and then introduced aseptically into sterile slant culture tubes of agar-agar and fermented banana filtrate. If no yeast developed around the pupae which were placed on the food the tube remained sterile after the emergence of adults, oviposition and hatching of larvae. The sterility of the tube was later tested by introducing a few loopfuls of the medium into a sterile tube of similar food. It had previously been determined that yeast developed readily on fermented banana agar. This is probably due to the catalytic action of dead yeast,[5] and the abundance of nutrition supplied by the banana.[6]

(2) Larvae which had been feeding on media containing living yeast cells were submerged and washed in 85% alcohol and then introduced into sterile culture tubes. In all cases yeast developed on the new media. Cultures from the digestive tracts of the larvae gave similar results. Apparently many cells escape digestion in the stomach as is the case with seeds or insect eggs in birds.

(3) Eggs were sterilized by soaking in 85% alcohol for ten minutes. The larvae which hatched were always aseptic.

From the foregoing experiments we may conclude that yeast is not present in the eggs or pupae of Drosophila. However, a loose symbiosis exists between the two organisms. As mentioned above, surface fungus growths disappear in the presence of larvae which often seemed to be more numerous at this point. From these observations I inferred that the larvae fed upon the microorganisms present.

The problem was attacked by the use of several different media. Two dozen large ripe bananas were fermented overnight by adding 24 grams of compressed bread yeast separated in a few cubic centimeters of water. The banana was thoroughly mashed before fermentation. This material was pressed through a sugar sack giving 1200 cc. of fluid.

Medium A consisted of this fluid, diluted twice with enough powdered agar-agar added to make up to 1.5%, then boiled, poured into test tubes and plugged with nonabsorbent cotton and sterilized in the autoclave for twenty minutes at 19 pounds pressure with vacuum at start.

Medium C consisted of 12 grams yeast per 200 cc. tap water and 1.5% agar-agar.

Medium D consisted of tap water and 1.5% agar-agar.

Medium J consisted of grape sugar, cane sugar, ammonium tartrate, citric acid, K_2HPO_4,$MgSO_4$,H_2O (proportions as used by Loeb[7]), 1.5% agar-agar. This was sterilized three successive days in Arnold Sterilizer.

The rates of development of larvae on these media were as follows:

	MEDIA	AVERAGE NUMBER OF DAYS	GROWTH
A	Aseptic fermented banana agar	28	From hatching to death
A	Septic fermented banana agar	12	From hatching to pupation
C	Aseptic yeast agar	9	From hatching to pupation
D	Aseptic agar	5	From hatching to death
D	Septic agar	26	From hatching to pupation
J	Aseptic synthetic medium	5	From hatching to death
J	Septic synthetic medium	10	From hatching to pupation

Aseptic larvae on A developed at half of the rate of septic larvae on the same medium. The growth of these retarded individuals could be greatly accelerated by adding two loopfuls of septic A to their food. This was done in the case of larvae which in twenty-six days have only reached a length of 2.5 mm. After three days the larvae were 4 mm. long and had doubled in diameter; another millimeter was gained the next day and on the sixth day the larvae formed pupae from which large adults emerged. Since larvae grow more rapidly on abundant dead yeast (C) than on less abundant living yeast, the fungus is merely the food of the insect.

It is apparent from the foregoing that the rate of growth is dependent on the abundance of yeast in the media. Dead yeast serves equally well in determining this rate. We may therefore conclude that yeast serves as food for Drosophila larvae. There is also evidence that other microorganisms may furnish nutrition for these flies. For example flies were reared from egg to adult on agar-agar (D) which had been contaminated by a living anaërobic bacterium as yet undetermined.

After the initiation of these experiments I found that Delcourt and Guyenot[8] and Guyenot[9] had already shown that yeast and most bacteria are of value to Drosophila larvae, especially when the larvae are in large numbers. These investigators finally obtained aseptic flies by the use of media unfavorable to the different forms of bacteria. Yeast persisted longest but was finally eliminated by using food consisting of sterile yeast, water and cotton. Potato media were occasionally intercalated in the series as a test of the absence of living yeast cells. The transference of flies was made aseptically by the use of an ingenious suction apparatus. However, females from stock which had been 'aseptic' for several generations occasionally deposited septic eggs and died in the center of a yeast colony. It is possible that living yeast was constantly present and that usually an insufficient number of cells was carried to the potato medium. In such a case due to the absence of bios,[9, 10,] growth would not take place. Guyenot later[11] reported that he had been able to raise Drosophila on sterile (unfermented) potato, but the percentage of larvae that pupated was small. Salomon[12] has described the use of yeast as a food for man and a considerable literature deals with its use as food for farm animals. Schultze[13] has suggested that Drosophila larvae may feed upon bacteria and yeasts in strange media such as sap, feces, formol, tumors, etc., from which the fly has been recorded. Henneberg[14] believes that these larvae feed upon microorganisms at the surface of vinegar.

It is probable that the food relations pointed out in my experiments are common to a number of organisms. The house fly, for example, oviposits only in the presence of the odor of fermentation, always has a certain form of bacteria on its body in great abundance and the larva is unable to survive in garbage which gives an acid reaction. Those insects which live in strange media such as strong salt water and petroleum may be associated with microorganisms which have unusual power of oxidation. It is likely that the vinegar eel will be found to be similarly associated with bacteria or fungi.

In 1915 Loeb[7] raised Drosophila on a synthetic medium consisting of inorganic salts, sugars and ammonium tartrate. He believed the synthetic power of the fly to be as great as that of bacteria. Later[15], however, he pointed out that the medium used "is a well known culture medium for certain microorganisms; e.g., yeast cells which are capable of synthesizing their proteins and other complicated organic compounds from ammonium salts."[16]

It is very evident from my experiments that the food of Drosophila larvae is yeast. The insect depends upon these cells for its proteins and has no greater synthetic power than is common to higher animals. Adult flies do not require proteins but survive for a much longer period on sugar agar than upon yeast agar. This difference between the nutritional requirements of larva and adult is probably due to the rapid growth in the former which requires proteins and leads to fatal changes in their absence.

Owing to the habit of the larvae of constantly agitating the surface and carrying yeast cells throughout the medium, fermentation is greatly increased and the increase in alcohol resulting may serve as a protection to the larvae against destructive molds and putrefactive bacteria. The anaërobic conditions resulting may increase the percentage of the albumin in the yeast cells[17] and thus increase their food value.

The number of larvae present in a culture determines the degree to which the yeast will be spread through the medium. If few larvae are present the cultures become contaminated with injurious molds and bacteria; if a large number of larvae is present the food remains 'sweet.'

The depth to which the larvae work their way below the surface is an important factor in this connection. This depth is determined by the consistency of the medium, as the larvae will go as deep as a bubble of air will remain attached to the two projecting posterior spiracles. The instant this bubble is lost the larva 'backs-up' until another is found. It would seem therefore that a medium of a jelly-like homogeneous consistency would be best, and I believe the geneticists are striving for this end when they mash and boil their banana.

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[1] Baumberger, J. P., and Glaser, R. W., *Science, New York*, N. S., **45**, 1917, (21–22).

[2] Bogdanow, E. A., *Arch. Anat. Physiol., Physiol. Abth., Leipzig*, 1908, Supple., (173).

[3] Buchner, P., *Arch. Protistenkunde, Jena*, **26**, (1–116).

[4] Glasgow, H., *Biol. Bull., Woods Hole, Mass.*, **26**, (101).

[5] Moufang, E., *Wochenschr. Brau., Berlin*, **30**, (113–116).

[6] Nagel, C., *Zs. Spirit Ind., Berlin*, **35**, (185).

[7] Loeb, J., *Science, New York*, N. S., **41**, 1915, (169–170).

[8] Delcourt, A., and Guyenot, E., *Bull. sci. France Belgique, Paris*, **45**, 1912, (249–332).

[9] Wildier, E., *La Cellule, Louvain*, **18**, (314–332).

[10] Harden, A., and Young, W. J., *London, Proc. R. Soc.* **78B**, (369–375).

[11] Guyenot, E., *Paris, C. R., soc. biol.*, **45**, pt. 1, 1913, (178).

[12] Salomon, *Münchener med. Wochenschr.*, **63**, 1916, (445).

[13] Schultze, P., *Zool. Anz., Leipzig*, **39**, (199–202).

[14] Henneberg, W., *D. Essigind., Berlin*, **6**, 1902, (333).

[15] Loeb, J., *J. Biol. Chem., Baltimore*, **23**, (2–5).

[16] After sending this paper to press, I learned that Loeb and Northrop, *J. Biol. Chem., Baltimore*, **27**, 1916, (309–312), had already published a confirmation of Guyenot's conclusion.

[17] Schoenfeld, F., and Hirt, W., *Wochenschr. Brau., Berlin*, **29**, (157–159, (174–178)).